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RESIDUAL STRENGTH ANALYSES OF MONOLITHIC STRUCTURES

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FOREWORD

This a progress report on the research work completed on the project "Two and Three Dimensional Elastic-Plastic Finite Element Analyses of Tapered Lok Fasteners and Residual Strength Analyses of Integral Stiffeners." This work was done under the subcategory " Residual Strength Analyses of Monolithic Structures," and specific attention was directed on investigation of crack branching and residual strength prediction with three (ZIP3D, STAGS3D) and two dimensional (STAGS) finite element codes.

This work was supported by the NASA Langley Research Center through the Cooperative Agreement NCCI-371. The Cooperative Agreement used to be monitored by **Dr. Richard. D. Young** and now it is being monitored by **Dr. Scott Forth** and **Dr. Damodar R. Ambur,** Head, Mechanics and Durability Branch, Mail Stop 188E, NASA Langley Research Center, Hampton, Virginia 23681-0001.

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B. R. Seshadri [#] and S. N. Tiwari [*]

SUMMARY

Finite-element fracture simulation methodology has been very well established to predict the residual strength of damaged aircraft structures. Over the years, this methodology has been experimentally verified at NASA Langley for structures ranging from laboratory coupons up to full-scale built-up structural components with single and multiple-site damage cracking. The methodology uses the critical crack-tip-opening-angle (CTOA) fracture criterion to characterize the fracture behavior of the material. The CTOA fracture criterion assumes that stable crack growth occurs when the crack-tip angle reaches a constant critical value. The use of the CTOA criterion requires an elastic-plastic, finite-element analysis. The critical CTOA value is determined by simulating fracture behavior in laboratory specimens, such as a compact specimen, to obtain the angle that best fits the observed test behavior. The critical CTOA value appears to be independent of loading, crack length, and in-plane dimensions. However, it is a function of material thickness and local crack-front constraint. Modeling the local constraint requires either a three-dimensional analysis or a two-dimensional analysis with an approximation to account for the constraint effects. In recent times as the aircraft industry is leaning towards monolithic structures with the intension of reducing part count and manufacturing cost, there has been a consistent effort at NASA Langley to extend critical CTOA based numerical methodology in the analysis of integrally-stiffened panels.

In this regard, a series of fracture tests were conducted on both flat and curved aluminum-alloy integrally-stiffened panels. These flat panels were subjected to uniaxial tension and

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during the test, applied load-crack extension, out-of-plane displacements and local deformations around the crack tip region were measured. Compact and middle-crack tension specimens were tested to determine the critical angle (ψ_c) using three-dimensional code (ZIP3D) and the plane-strain core height (h_c) using two-dimensional code (STAGS). These values were then used in the STAGS analysis to predict the fracture behavior of the integrally-stiffened panels. The analyses modeled stable tearing, buckling, and crack branching at the integral stiffener using different values of critical CTOA for different material thicknesses and orientation. Comparisons were made between measured and predicted load-crack extension, out-of-plane displacements and local deformations around the crack tip region.

Simultaneously, three-dimensional capabilities has been developed at NASA Langley to model crack branching and to monitor stable crack growth of multiple cracks in a large thick integrally-stiffened flat panels. These new features were implemented in three-dimensional finite element code (ZIP3D) and they were tested very recently by analyzing the integrally-stiffened panels tested at Alcoa. The residual strength of the panels predicted from STAGS and ZIP3D code compared very well with experimental data. In recent times, STAGS software has been updated with new features and now one can have combinations of solid and shell elements in the residual strength analysis of integrally-stiffened panels. These new features have been well tested with experimental data. These recent developments in the analysis of integrally-stiffened panels at NASA Langley form the highlight of this report.

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LIST OF SYMBOLS

Unless otherwise stated, the listed symbols are specified as follows

$2a_i$	Initial crack length crack, in.
$2a_f$	Fatigue crack length crack, in.
B	Specimen thickness, in.
d	Minimum element size along crack line, in.
h_c	Plane-strain core height, in.
E	Young's modulus, ksi
K	Stress intensity factor, ksi$\sqrt{in.}$
P	Applied load, kips
S	Applied stress, ksi
W	Width of specimen, in.
X,Y,Z	Cartesian coordinates
ν	Poisson's ratio
δ_5	Crack opening displacement, in.
ψ_c	Critical crack tip opening angle, (CTOA), deg.
σ_{ys}	Yield stress, ksi
σ_u	Ultimate tensile strength, ksi

LIST OF FIGURES

INTRODUCTION

Recently, the aircraft industry is exploring the prospect of replacing built-up structures with integral structures for aircraft applications. With the emergence of high speed machining and improvements in other manufacturing technologies, there is a great promise to greatly reduce part count and manufacturing cost [1,2], but methods need to be developed to predict the residual strength of these structures. As part of the NASA Airframe Structural Integrity Program [3], a fracture simulation methodology based on the critical-crack-tip-opening angle (CTOA) has been developed to predict the strength of damaged aircraft structures. The methodology has been experimentally verified for structures ranging from laboratory coupons up to full-scale built-up structural components with single-crack and multiple-site cracking [4]. Efforts are under way at NASA Langley to extend this methodology to the new integral structures under evaluation by the aircraft industry. These extensions include modifications that account for crack branching into integral stiffeners and thickness variations in the panel. To validate these methods, a series of flat integrally-stiffened panels were designed and tested for residual strength at the NASA Langley Research Center. On similar lines, the Alcoa technical center is also working towards design and fabrication of integral structures for aircraft applications. In this regard, as part of preliminary study, a series of integrally-stiffened thick panels were tested. In parallel with the test programs at NASA Langley and the Alcoa Technical Center, series of analyses were conducted at NASA Langley in the residual strength prediction of integrally-stiffened panels using the CTOA criterion. This report reviews some of the milestones accomplished in the residual strength prediction methodology for integrally-stiffened panels.

EXPERIMENTS

Fracture tests on standard laboratory fracture specimens and on 40-inch wide integrally-stiffened panels were conducted at the NASA Langley Research Center (LaRC). The laboratory specimens and the integral panels were made of 7475-T7351 aluminum alloy material. All of the laboratory specimens were tested with anti-buckling guides. Both compact tension, C(T), and eccentrically-loaded singe edge tension, ESE(T), specimens of various widths (W = 2 to 6 in) and thicknesses (B = 0.06 to 0.19 in) were tested. The specimen geometries and dimensions are shown in Figure 1. The integrally-stiffened panel shown in Figure 2, was machined from a 1.5-inch thick plate. Five Z cross-section integral stiffeners were located symmetrically across the width of the panel. The integral stiffeners were orientated in the direction of loading and perpendicular to the direction of the central offset lead crack as shown in this figure. Tests were conducted on two integrally-stiffened panels with different crack configurations. The first panel tested contained a single 8-inch long crack centered across, and severing the middle integral. The second panel tested contained a single 5.9-inch long lead crack located between second and third integrals as shown in Figure 2. The analysis results for the first panel compared well with the test data and it was presented at the previous aging aircraft conference. For more information on first panel test and analysis results, please refer to Reference 5. In this report, only the results from the analysis of second panel are compared with test data. During the tests, measurements were made of applied load, crack extension, crack opening displacements (δ_5) [6], out-of-plane displacement, stroke displacement, and strains in the crack-tip region and in the integral stiffeners. These panels were tested without anti-buckling guides.

On similar lines, a series of 20-inch wide integrally stiffened thick panels were tested at Alcoa. These panels were made of 2024-T351 and C433-T39 materials. The panel geometry and configuration is depicted in Figure 3. These panels were also machined from 1.5-inch thick plate. For more information on Alcoa panel test results and procedure followed, please refer to Reference 7.

ANALYSES

The fracture analyses of all laboratory specimens tested at NASA Langley were conducted using both WARP3D [8, 9] and STAGS (STructural Analysis of General Shells) [10] codes with the constant critical crack-tip-opening angle (CTOA) fracture criterion [11]. STAGS is a finite element program for the analysis of general shell-type structures [10]. The program has several types of analysis capabilities (static, dynamic, buckling, crack extension, material nonlinear and geometric nonlinear behavior). STAGS has crack extension capability based on the critical crack-tip-opening angle or displacement (CTOA or CTOD) criterion, the T*-integral and the traditional K_R-curve. In the current study, quadrilateral shell elements with 6 degrees-of-freedom per node (three displacements and three rotations) were used in the model. The quadrilateral shell element was under 'plane-stress' conditions everywhere in the model except for a 'core' of elements along the crack plane that were under 'plane strain' conditions [13]. Elastic-plastic material behavior of the sheet and stiffener were approximated by multi-linear stress-strain curves. The White-Besseling plasticity theory was used to account for yielding and reverse yielding [10]. The analysis methodology followed and the calibration procedure adopted in the determination of fracture parameters are discussed in the following sections.

Analysis Methodology

The analysis methodology used to characterize the critical CTOA value (ψ_c) for each material thickness was to match the maximum load from the analysis with the average maximum load for the tests. Three-dimensional finite element analyses with the small strain option (for consistency with the STAGS small strain formulation) were used to find the critical angles. By using these angles in the STAGS analyses, the plane-strain core heights were estimated. The determination of critical angle and plane-strain core height will be discussed in the following section.

The CTOA fracture criterion assumes that stable crack growth occurs when the crack-tip angle reaches a constant critical value and requires an elastic-plastic finite-element analysis [11]. The critical angle appears to be independent of loading, crack length, and in-plane dimensions, if the crack length and remaining ligament are greater than approximately 4 times the sheet thickness. However, CTOA is a function of material thickness and local crack-front constraint. The critical CTOA criterion is equivalent to a critical CTOD value at a specified distance behind the crack tip [12].

At each load increment, the CTOA is calculated at a fixed distance behind the current crack tip and compared to a critical value (ψ_c). When the CTOA exceeds the critical value, the crack-tip node is released and the crack is advanced to the next node. This process is continued until crack growth became unstable under load control or until the desired crack length is reached under displacement control (herein, all analyses were run in displacement control). As the crack grows with stable tearing in the integral panel, the crack tip passes through sections of various thicknesses. In addition, when the lead crack approaches and severs an intact integral stiffener, crack branching occurs. With crack branching (Fig 4), crack growth of multiple cracks is controlled by different values of critical CTOA at each crack tip. To carry out stable tearing analysis with STAGS, the critical CTOA, which governs the onset of crack growth, and the plane-strain core height, which simulates the three-dimensional constraints around the crack-front region, needed to be determined. For this purpose, the load-crack-extension results from the C(T) and ESE(T) specimens that were restrained from buckling were used.

The concept of defining plane-strain elements around the crack-front region [13] is adopted in two-dimensional analysis to simulate three-dimensional constraint conditions around a crack front. Previous analyses of wide flat panels [4,13] have shown that the high-constraint conditions around a crack front, which can be approximated as plane strain, must be modeled in order for the critical CTOA criterion to predict wide panel failure from small laboratory tests. The plane-strain core is defined as a strip of elements parallel to the crack plane with a half-height of h_c. The plane strain core height for each material thickness was determined by adjusting the core height such that the maximum load from the analysis approximately matches the maximum load from the test. In each case, the critical angle obtained from the respective three-dimensional analysis was used.

Minimum Element Size

To model the fracture process with the CTOA failure criterion, an array of small elements was positioned along the crack symmetry plane. Previous parametric and convergence studies showed that a uniform crack-tip element size of 0.04-in. (linear-strain element) was sufficient to model stable tearing under elastic-plastic conditions [14]. Crack growth was governed by monitoring the critical CTOA (Ψ_c) at a distance of 0.04-in. (one element) behind the crack tip.

Accounting for Buckling and Crack Branching

Seshadri and Newman [4, 15] have demonstrated that stable tearing in the presence of buckling can be predicted with STAGS and the CTOA fracture criterion. A bifurcation analysis was conducted to determine the first buckling mode shape. This out-of-plane displacement shape (about 10% of the sheet thickness) was then introduced as an imperfection in the model for the non-linear analysis. When the lead crack approaches the intact integral stiffener during stable tearing, the crack branches into two with the main lead crack continuing along the X-direction in the panel and the secondary crack growing along the integral stiffener. Figure 4 shows a schematic representation of crack branching. Each material thickness and orientation has a separate critical crack tip opening angle.

Determination of Critical CTOA and Plane Strain Core Height

The analysis results for the 6-inch wide, B = 0.06 inch thick C(T) specimen are compared with the experimental data in Figure 5. In this figure, open symbols show results from the three tests: two that failed in traditional slant fracture (single 45 deg. slant through the thickness) and one that failed in partial V-shear fracture. The V-shear fracture test resulted in a higher maximum load than the single shear tests. WARP3D and STAGS analyses results are represented by solid and dashed lines, respectively. The critical angle that allows the WARP3D analysis to match the average experimental maximum load is 6.5 degrees. The analysis results for the 2-inch and 4-inch wide C(T) specimens matched the experimental maximum load within 2.5 % (not shown).

Figures 6 and 7 show the analysis results that best matched the experimental data for the 4-inch wide, 0.17-inch thick C(T) specimen, and for the 1.4-inch wide 0.08-inch thick ESE(T) specimens, respectively. The WARP3D analysis results ($\psi_c = 7.3$ deg.) in Figure 6 for the C(T) specimens are remarkably close to the test data. The results in Figure 7 for the 1.4-inch ESE(T) specimens are very good for the single specimen that failed in traditional slant fracture. However, the other three specimens displayed pop-in at maximum load. Cracking appears to have started on a plane perpendicular to the crack front (TL) at the fatigue crack front (The ESE(T) does have a positive T-stress that results from the bending moment generated by the loading for this specimen). Small amounts of crack growth also proceeded on the crack plane. At the maximum load, the crack extended in an unstable manner. During this fracture process, the specimen experienced V-fracture followed by a slant fracture. The average maximum load for the V-fracture specimens is 15% above the maximum for the simple slant fracture specimen. For more information on laboratory test results and there interpretation please refer to Reference 5.

The dashed lines in Figures 5-7 show the STAGS results that best match the experimental results. In all cases, the STAGS analysis results compared very well with the test data and three-dimensional WARP3D analyses. Once the required plane strain core heights were determined for various thicknesses, the residual strength analysis of the 40-inch wide integral panel was performed with the STAGS finite element code.

FRACTURE ANALYSES OF 40-INCH WIDE INTEGRALLY STIFFENED PANELS

The STAGS finite-element shell code and the critical crack-tip-opening angle (CTOA) failure criterion were used to model stable tearing of cracks and to predict residual strength behavior of the integral panel fracture tests. Figures 2, 4 and 8 show the integrally stiffened panel configuration and a typical finite-element model of the panel used in the analysis. Because the configuration and loading were symmetric about the crack plane, only half of the panel was modeled. Figure 8 shows only the mesh pattern near the crack. The remote loading was applied as uniform displacement. This model contained 20,559 nodes, 15,255 shell elements and 127,422 degree-of-freedom (DOF). The following sections discuss the stable crack growth analyses of the integrally stiffened panels. Load crack extension data, local displacement measurements, strain gage readings and load carried by the integral stiffeners from the STAGS analysis are compared with the test data.

Comparison of Load-Crack Extension Results

Figure 9 show the test measurements (open symbols) and analytical prediction (solid line) corresponding to right crack tip. As mentioned before, the panel tested had 5.9 inch lead crack located between second and third integral stiffeners as shown in Figure 2. The insert shows the relative location of the integral stiffener close to the right crack tip. After pre-cracking, a small circular notch was created in front of left crack tip to prevent further growth. The circular notch acts as a crack arrester and only the right crack tip continues to advance with further loading. Figure 9 shows that failure occurred when the right crack tip reached the edge of the integral stiffener (solid symbol). The analysis predicted similar behavior; the crack growth became unstable when the crack tip entered the integral stiffener. The load-crack extension data from the analysis very well compared with the test measurements and the failure load predicted from the STAGS analysis was within 3% of test failure load.

Comparison of Strain Gage Measurements

Analysis results are compared with local strain gage readings in Figures 10-12. The integral panel had strain gages mounted at several distinct locations on the sheet and on the stiffeners (front and back). Three sets of strain gage data were considered for comparison; gages that are 20.2-inches above the crack symmetric plane; gages that are 2-inches above initial crack tip locations and gages on the intact integrals along crack symmetric plane.

The first set of strain gages recorded the remote strain history away from the crack symmetric plane. Figure 10 shows the comparative results for all the strain gages. Symbols (open and solid) and lines represent experimental and analytical results respectively. As expected all these remote gages record uniform amount of stain with increase in applied load and there is a linear relationship as the deformation confines to elastic. The STAGS analysis results represented by lines compare very well with test results. It infers that, the load is getting transferred quite accurately in the finite element simulation of the integrally-stiffened panel.

The second set of strain gages was located on the sheet surface and they were 2 inches above the initial crack symmetric plane. The comparative results are shown in

Figure 11. The test and analysis results are represented by symbols and lines respectively. With increase in applied load, the right crack tip continues to grow towards right material point and there is a continues build of strain as indicated by both front and back right strain gages (solid symbols). To begin with, the left crack tip has already passed the left material point and due to this, gages located at left material point won't see any build of strains. Its indicated by both front and back left strain gages (open symbols). The analysis results represented by lines very well capture this behavior at these locations and compares well the strain gage measurements.

The third set of strain gages were located on the interior left and right integral stiffeners. Figure 12 shows comparative results. Symbols correspond to test measurements and the lines represent analytical results. As expected, at these locations, there is continuous build up of strain with increase in applied load. The analysis very well captures this behavior from the beginning and compares very well with test data till failure load.

FRACTURE ANALYSES OF 20-INCH WIDE INTEGRALLY STIFFENED THICK PANELS

On similar lines, 20-inch wide integrally stiffened thick panels were analyzed for residual strength evaluation using both ZIP3D [16] and STAGS codes. As mentioned before, these panels were tested at the Alcoa technical center and few of the panels tested were analyzed. For more information on the tests results and procedure adopted, please refer to Reference 7. ZIP3D is an elastic-plastic material non-linear finite element software with capabilities to carryout fatigue and fracture analysis. It has geometric linear capability which works very well for thick panels where in buckling is not a major issue. For more information on fatigue and fracture capabilities of ZIP3D, refer to Reference 16. Recently, ZIP3D finite element software has been updated with new capabilities and features to analyze integrally-stiffened thick panels. With new features, ZIP3D now has the capability to analyze integrally-stiffened panels with lead crack branching into multiple secondary cracks along the various intact integrals. The crack growth of these secondary cracks is controlled by independent critical crack tip opening angles. As detailed in previous sections, similar procedures were adopted in the residual strength analysis. These panels were made up of different materials namely, 2024-T351 and C433-T39. So, corresponding to each of these materials, 16-inch wide, B = 0.25 inch thick M(T) specimens were tested at Alcoa and these test results were used in calibrating critical crack tip opening angles and plane strain core heights by following the similar procedures detailed in earlier sections.

The analysis results for the 16-inch wide 2024-T351 M(T) specimen are compared with the experimental data in Figure 13. In this figure, open symbols correspond to test results. ZIP3D and STAGS analyses results are represented by solid and dashed lines, respectively. The critical angle that allows the ZIP3D analysis to match the experimental maximum load is 5.1 degrees. By using same critical angle (5.1 deg.) and by modeling three-dimensional constraint around the crack tip with a plane strain core height of 0.25 inches, STAGS analysis was able to match the experimental maximum load quite accurately. Later on these calibrated parameters were used in the residual strength prediction of 20-inch wide integrally stiffened thick panel.

On similar lines, test results from 16-inch wide M(T) specimen made up of C433-T39 material were used in the calibration of critical crack tip angle and plane strain core height. Experimental data and analysis results are compared in Figure 14. Test and analyses (ZIP3D and STAGS) results are represented by open symbols and lines respectively. The critical angle that allows the ZIP3D analysis represented by solid line to match the experimental maximum load is 6.5 degrees. STAGS analysis results with the same critical angle of 6.5 deg. and a plane strain core height of 0.25 inches is represented by dashed lines. Both ZIP3D and STAGS analyses results very well match the experimental maximum load. As mentioned before, these calibrated parameters were used in the residual strength prediction of 20-inch wide integrally stiffened thick panel.

For the earlier 40-inch wide integral panel analyzed, different critical crack tip opening angles were calibrated for various thicknesses across the cross section. Where as for the Alcoa panels, the thickness across the integral being the same as sheet thickness, the same critical angle was used for the lead crack as well as for the cracks branching along the intact integrals. Schematically this has been represented in Figure 15 and it holds good for both (2024-T351 and C433-T39) the panels analyzed.

A typical test set up used to test the integral panels at the Alcoa technical center is shown in Figure 16. On the left hand side is a typical integral panel with fixtures being loaded in the test machine. On the right hand side, the top and bottom figures show the crack approaching and leaving the integral respectively. All these panels were subjected to fatigue loading till the desired crack length was reached and from then onwards they were tested for residual strength. For residual strength analysis, the crack length just prior to the beginning of the residual strength test was considered. For more information on test results and procedures follow, please refer to Reference 6.

Figures 3 and 17 show the integrally stiffened thick panel configuration and a typical finite-element model of the panel used in the analysis. Because the configuration and loading were symmetric about the crack plane and y-z plane only one quarter of the panel was modeled. Figure 17 shows both global and local mesh pattern used near the crack in ZIP3D and STAGS analysis. The remote loading was applied as uniform displacement. The ZIP3D model contained 24,444 nodes and 19,584 brick elements and STAGS model has 6047 nodes and 5022 shell elements. In spite of having comparatively such a large finite element model, the new solver implemented in ZIP3D is relatively 12 times faster than the earlier one and each analysis is completed well within 3 hrs of execution time. In comparison, STAGS analysis takes around 21/2 hrs of execution time. Load crack extension results from both ZIP3D and STAGS analysis are compared with the test data.

Also, an attempt was made to analyze 20-inch wide integrally-stiffened thick panels with solid and shell elements by using new capabilities in STAGS finite element software. For this purpose, a finite element model with solid and shell elements was generated. A typical schematic representation of such a FE model is depicted in Figure 18. By using solid elements along the crack symmetric plane, the three dimensional constraint condition around the crack tip region is automatically imposed in the model and there is no necessity to calibrate plane strain core height from the analysis. By using solid and shell elements in tandem, only CTOA needs to be calibrated from laboratory specimens. With this new feature, now one can capture severe out of deformations in the structure by using non-linear shell elements everywhere except near the crack tip region and model crack tip region with solid elements.

Comparison of load-crack extension results for 20-inch wide integrally-stiffened panel made up of 2024-T351 is shown in Figure 19. As experimental load-crack extension data was not available for comparison, only maximum load is indicated by horizontal dashed line. Solid, dash-dot-dot and dash-dot lines indicate the ZIP3D and STAGS analyses results respectively. The insert shows the location intact integral. STAGS analysis results with solid and shell elements represented by dash-dot line compare very well with other analyses results. Both ZIP3D and STAGS analysis results compare very well with the experimental maximum and they are within two percent of the test max load. Both the analyses have similar characteristics and once the lead crack passes the integral, the crack growth becomes unstable.

On similar lines, load-crack extension data for C433-T39 integral panel is shown in Figure 20. Once again, the experimental maximum load is indicated by horizontal dashed line. Solid, dash-dot-dot and dash-dot lines represent both ZIP3D and STAGS analyses results respectively. For this material, a critical crack tip opening angle of 6.5 deg. was used in both ZIP3D and STAGS analysis. Even for this panel also, as soon as the lead crack passes the intact integral, the crack growth becomes unstable. All the three analyses results compare very well with test data and they are within two percent of test data.

CONCLUSIONS

The STAGS finite-element code and the CTOA fracture criterion were used to predict stable tearing and residual strength of an integrally-stiffened panel made of 7475 aluminum alloy. By using critical crack tip opening angles and plane strain core heights calibrated from laboratory coupons, the residual strength of 40-inch wide integrally stiffened was predicted using STAGS and it was within 3% of the test failure load. The strain gage readings from the analysis for various sheet and integral locations compared very well with the test measurements, which indicate that, the overall load transfer and load distribution is correct. ZIP3D and STAGS residual strength prediction of 20-inch wide integrally stiffened Alcoa thick panels made up of both 2024-T351 and C433-T39 compared very well and they were within 2 % of experimental maximum loads. By using solid and shell elements in STAGS analysis, plane-strain core height calibration can be totally eliminated and only critical CTOA is required in residual strength prediction. These studies have demonstrated that both STAGS and ZIP3D have all the capability and features that are required in the analysis of both thin and thick integrally stiffened panels. These analysis codes will be enhanced as necessary in near future. With the success in the fracture analyses of cracked integrally-stiffened panels, the finite-element software and CTOA fracture criterion may be useful in the fracture design of integrally-stiffened thin and thick structures.

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ODURF **320481** Trace Metal Spciation J. Donat

06/17/2003 15:00

5120 Faculty Direct Payments					0.00	0.00	
5130 Graduate	11,800.00	11,799.92			11,799.92	0.08	
5131 Casual	8,095.00	3,830.00		4,090.92	7,920.92	174.08	Piraneo'S
5132 Technical					0.00	0.00	
5180 Faculty Release Time	19,467.00	6,489.00		12,978.00	19,467.00	0.00	Summer'03-Summer '04 FRT
5190 Other Professional	49,418.00	32,823.01	5,753.84		38,576.85	10,841.15	
5200 Control Fringes					0.00	0.00	
5201 Fica 6.2%	4,357.00	2,432.95	371.25	253.64	3,057.84	1,299.16	
5202 Fica Health	5,810.00	4,050.41	702.30	59.32	4,812.03	997.97	
5203	578.00	322.62	54.28		376.90	201.10	
5206 Fica 1.45%	1,019.00	568.98	86.82		655.80	363.20	
5209 Unemployment Taxes	460.00	394.01	28.11	63.41	485.53	(25.53)	
5210 Computed Fringe Benefits	5,061.00	1,687.14		3,373.56	5,060.70	0.30	Summer'03-Summer '04 FRT's Fri
5260 Vacation Leave	3,799.00	2,035.22	345.22		2,380.44	1,418.56	
5261 Sick Leave Pool	1,266.00	678.33	115.06		793.39	472.61	
5262 Tuition	317.00	169.64	28.78		198.42	118.58	
5290 Fringe	6,963.00	3,745.77	632.94		4,378.71	2,584.29	
5300 Exp		41.79			41.79	(41.79)	
5399 Supplies Control	13,817.00	9,346.06	730.00	3,740.94	13,817.00	0.00	
5501 Postage	3,950.00	1,344.91			1,344.91	2,605.09	
5507 Pub's Subscriptions	219.00	219.00			219.00	0.00	
5601 Domestic Travel	3,425.00	3,424.61			3,424.61	0.39	
5603 Foreign Travel	7,589.00	7,588.30			7,588.30	0.70	
6000 Indirect Costs	61,912.00	38,164.93	0.00		38,164.93	23,747.07	

% of total budget spent **67%**

5131	Piraneo	Senya	4090.92			05/04/2003	07/26/2003
5190	Morton	Peter	35830.71			07/14/2002	07/31/2003